Very Low Energy Proton-Proton Scattering and Scaler Meson Exchange (Memorial Issue Dedicated to the Late Professor Yoshiaki Uemura)

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The P-wave phase shifts and their mean value ${}^3\Delta_c$ are calculated by the One Boson Exchange [OBE] model. It seems to be difficult to reproduce consistently ${}^3\Delta_c$ below 25 MeV and $\delta({}^3P_0)$ below 300 MeV. And we show that ${}^3\Delta_c$ is a very sensitive parameter to the "scaler meson" exchange in the OBE model.

It is known that in the case of very low energy proton-proton scattering, almost a unique set of the phase shifts, $\delta({}^1S_0)$ and ${}^3\Delta_c$, can be got by analyzing differential cross section data only.[1] We denote ${}^3\Delta_c$ as the P-wave mean phase shift which can be written as follows,

$$ {}^3\Delta_c = \frac{1}{9}\{\delta({}^3P_0) + 3\delta({}^3P_1) + 5\delta({}^3P_2)\} $$

Below 10 MeV, the high precision measurements of the proton-proton differential cross sections were done at Wisconsin,[2] Minesota[3] and Berkeley.[4] Recently, Sher *et al.*[5] analyzed these data including the Q.E.D. correction, and got an energy dependent solution below 25 MeV and energy independent solutions. They pointed out an incompatibility between the Berkeley data and the Minesota data. According to this appointment, the high precision measurements near 10 MeV were done again at Los Alamos[6] and Kyoto.[7] Their results seem consistent with the Minesota data.

As far as the Born approximation is good, ${}^3\Delta_c$ can be considered to the phase shift caused by a central force.[8] In this energy region, the central force mainly consists of the weak repulsive force by one pion exchange and the attractive force by the "scaler meson" exchange. And ${}^3\Delta_c$ is a very small value because of their delicate cancellation. Now one pion exchange is firmly established in this energy region, ${}^3\Delta_c$ is the very sensitive parameter to the "scaler meson" exchange mechanism.

In almost all analysis of the proton-proton data below the inelastic threshold by OBE model, the mass of the "scaler meson" is lighter than that of the vector mesons. For example, it is 450 MeV in the analysis of Furuichi *et al.*[9] However, such light scaler meson can not be found in pion-pion scattering experiments. It is still an open problem what is "the scaler meson" in OBE model.

Furuichi *et al.* and others insist that the "scaler meson" is the substitution of $I=0$ uncorrelated two pion exchange and they can get the smaller χ^2 than the analysis by the ordinary OBE model.[9,10]

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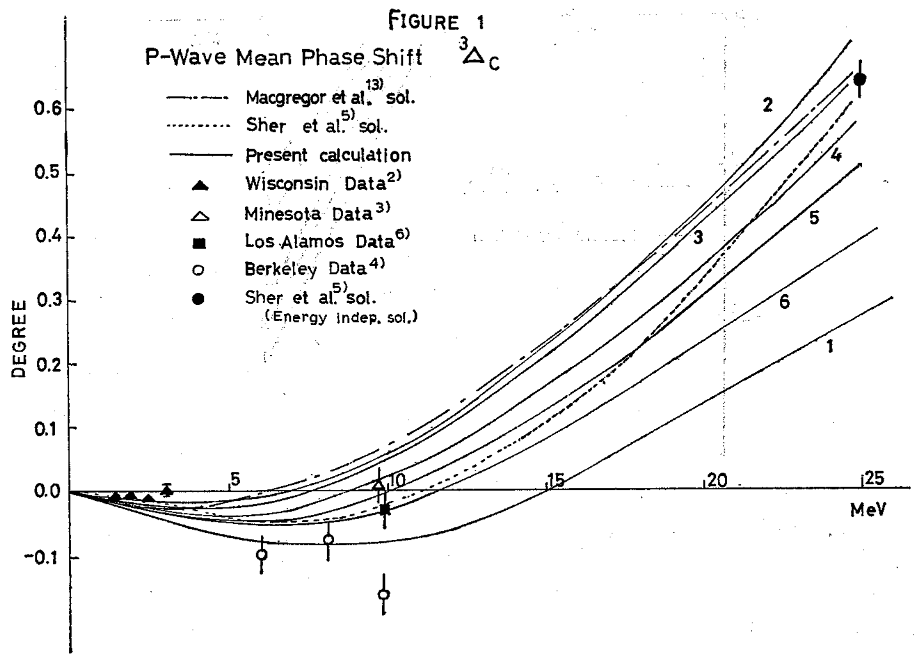
And Yonezawa *et al.*[11] pointed out the correspondency of the "scaler meson" to Pomeron.

Now, we calculated $^3\Delta_c$ by the ordinary K-matrix method to investigate the "scaler meson" phenomenologically. The results are shown in Fig. 1 and Fig. 2. The parameters of the bosons used in the calculation are shown in Table I.

Table I. Boson Parameters.

Boson NO.	π $M\pi$	$G\pi^2/4\pi$	ω $M\omega$	$G\omega^2/4\pi$	$\frac{G\omega f\omega}{4\pi}$	$f\omega^2/4\pi$	ρ $M\rho$	$G\rho^2/4\pi$	$\frac{G\rho f\rho}{4\pi}$	$f\rho^2/4\pi$	$I=0$ Scaler Ms	$Gs^2/4\pi$	$\omega+\rho$ $Gv^2/4\pi$
1	135	14.4	750	8.28	2.57	0.80	750	21.92	8.43	3.24	450	2.57	8.98
2	135	14.4	750	8.28	2.57	0.80	750	21.92	8.43	3.24	450	3.10	8.98
3	135	14.4	750	8.28	2.57	0.80	750	21.92	8.43	3.24	430	2.57	8.98
4	135	14.4	750	8.28	4.81	2.80	750	21.92	8.43	3.24	450	2.57	7.00
5	135	14.4	750	8.28	2.57	0.80	750	18.00	7.64	3.24	450	2.57	7.18
6	135	14.4	800	8.28	2.57	0.80	800	21.92	8.43	3.24	450	2.57	8.98

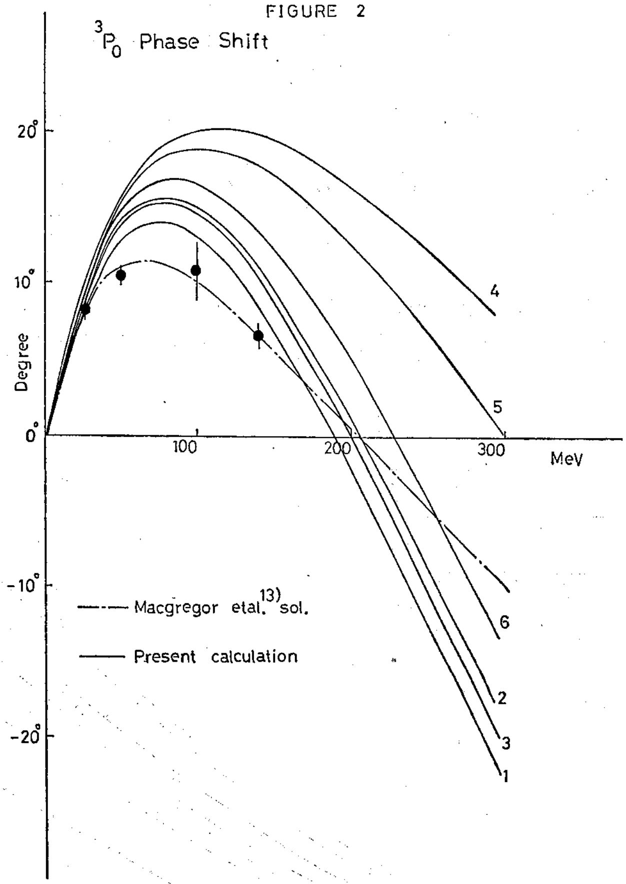
Parameters of NO. 1 were got by Furuichi *et al.* to fit the p-p phase shifts below inelastic threshold. $<Gv^2/4\pi>$ is "effective coupling constant" of vector mesons ρ, ω, which contributes to triplet odd central potential.



The boson parameters given by Furuichi *et al.*[9] using the energy independent solutions of MacGregor *et al.*,[12] can not reproduce $^3\Delta_c$. (See curve 1 in Fig. 1) If we take the stronger coupling constant or the lighter mass for the "scaler meson" in order to reproduce the experimental value of $^3\Delta_c$, the calculated value of $\delta(^3P_0)$ becomes fairly larger than the experimental one in the energy range $25 \approx 150$ MeV. (See curves 2 and 3, in Fig. 1 and Fig. 2)

We can find the same tendency but of an opposite sign in the case of varying the vector boson parameters. (See curves 4, 5, 6, in Fig. 1) This is because the vector boson exchange makes a repulsive central force. But, because of the heavier mass of the vector bosons, one must vary their parameters more largely than those of the "scaler meson" to reproduce $^3\Delta_c$. So the discrepancy between the calculated $\delta(^3P_0)$ and the experimental one becomes larger than in the case of the "scaler meson". (See curves 4, 5, 6, in Fig. 2)

FIGURE 2



To fit the experimental data, qualitatively, one must take the weaker coupling constant or the heavier mass of the "scaler meson", as the energy increase. In the case of the vector mesons, the parameters must have an opposite energy dependence to the case of the "scaler meson".

However, in the phase shifts got by MacGregor *et al.*,[13] especially $\delta(^3P_0)$ has a large error and several data have inconsistency in the energy range $25\sim100$ MeV. In this energy region, it will be important to make the error of $\delta(^3P_0)$ small and to determine the phase shifts at more energy points in order to know the energy dependence of this parameter. High precision measurements of some observables of the proton-proton scattering is expected in this energy region.

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